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EXPERIMENTAL SCIENCE AND WORLD GEOMETRY[1]

THE major advances in science are many-sided. Though led by men of exceptional genius they have always been natural outgrowths of the concepts and problems met with in preceding systems of ideas. They have had natural setting not only in the main current of science in the narrower sense but even in the general thought of mankind. They need to be viewed in varied ways, interpreted by persons of varied outlook and equipment, in order that both their powers and their limitations may be understood.

For my part in the present group of papers I have chosen a point of view indicated by the title and best described in the body of the paper. Some reasons for this choice are found in the flavor of recent discussions concerning the bearing of particular experiments on the future of the relativity theory, in particular on the oft-heard question whether it is true or false. Now it is apparent that some of the diversities of judgment and expectation on these matters are to be ascribed to differences of opinion as to the nature and possibilities of scientific theories altogether. We may never reach unanimity on this point. It is perhaps even probable that there will always remain ways of thinking so contrasted that according to one's philosophy any particular theory can be justly called either true or false. Since one main motive of a genuine relativity scheme of thought is the explicit recognition of a variety of points of view or "frames of reference," it would be consonant with the spirit of such a theory to welcome a variety of modes of judgment even as to its own truth and virtue. But it is important to remember that part of the discrepancies of judgment are due to double meanings in the language used, not easy to avoid and therefore needful to be noticed.

We ask whether an ether exists, whether space is actually curved, whether time is truly a fourth dimension, whether a body is really flattened when it moves. The meaning of the questions needs some explanation.

Clearly we do not show that an ether exists in all the senses in which we show that a gas exists. We pump gas out of a vessel and stop the passage of sound. No one claims yet to have pumped the ether out of a portion of space and stopped the passage

[1] Third paper of symposium on relativity, joint meeting of American Physical Society and Section B, American Association for the Advancement of Science, Kansas City, Mo., December 30, 1925.

of light. But we seem to be justified in understanding that a vacuum has a dielectric coefficient as much as glass or oil does.

That the space of astronomy is curved, in the sense that the surface of the earth is curved, by test after the methods of geodetic surveying, is a proposition we never expect to verify. But that the concept of a curved universe is likely to be useful in the future interpretation of data on the stars and nebulae has already been abundantly shown in connection with the cosmological geometries of Einstein and DeSitter.

That time is a fourth dimension on a parity with length in all respects, for instance, as fully as right-and-left is on a parity with up-and-down, sounds fairly like nonsense. But that a unified geometry of space and time measurements together, in the abstract logical sense of mathematical thinking, is not only possible but in fact a more naturally scientific and fertile mode of thought than its predecessors should be clear from the simple facts that the new theory contains the whole vital content of the older ones and that it owes its increased power to the rejection of certain restrictions and prepossessions which are now seen to have been due to arbitrary assumptions or misunderstandings rather than to really experimental knowledge. Einstein's theory is not likely to be the last instance of the purification of science in such fashion.

Whether any particular body is flattened as it moves depends on how it is set in motion, and this question is therefore best regarded as a matter of experimental test and decision so far as the precision attainable in such measurements permits. But that the Heaviside ellipsoid, for example, is a convenient standard or ideal of reference in a moving system should be clear from the new simplicity that the Lorentz-Einstein system of variables, with its flattening factor and related concepts, has brought into the treatment of aberration, Döppler effect, and the like.

More important for our present purpose it is that the word "space" has itself a dual meaning, not always attended to. Sometimes it means something like the aggregate of natural objects in some vague and meager sense such as to suggest that we are noticing only such relations as order, position, accessibility. Sometimes it means an aggregate of ideal elements called points in a purely conceptual scheme described by mathematical postulate and definition, and thus open to purely logical examination. Some kind of correspondence between the two is implied in practically all scientific work and is understood to be established sufficiently by a suitable use, in combination, of relevant observational data and of a more or less arbitrary mode of computation or graphing.

Prerelativity physics used a sort of disjointed correspondence, mapping observed events into a flat three-dimensional length-space and a one-dimensional time-space, with only occasional hints that a closer affiliation between these two spaces might be of interest. The special relativity scheme of Lorentz and Einstein, interpreted geometrically by Minkowski, uses as conceptual space a single four-dimensional flat space, comprehending both length and time relations. The general relativity substitutes a suitable curved space and with the increased resources thus supplied is able to annex the entire realm of general mechanics to geometric theory.

This "geometrizing" of physics is sometimes objected to, but on grounds that are far from clear. The matter deserves extended notice, but a suitable discussion can hardly be attempted here. A few other objections need at least to be referred to.

It is sometimes said that the relativity theory is mathematical rather than physical, as though these terms were mutually exclusive. One finds it hard to see how a physical theory of such scope could have the needed precision without mathematical formulation, and there seem to be reasons for conjecturing that "physical" occasionally means "metaphysical." Sometimes the theory is called too abstract, but one could hardly expect a combination of comprehensiveness and manageability without abstractness. Then it is said to work entirely with principles, not at all with physical pictures. This is in the main perhaps more a difficulty than an objection but it touches a point vital for many scientists and invites some comment. One aspect of the distinction thus made helps to set in a clear light, not only why the relativity movement was opportune, but why further developments of similar type are now urgently needed, especially in the field of what is commonly called molecular physics.

The distinction between abstract principles and physical pictures runs somewhat parallel to that other distinction, roughly possible in most scientific thinking, between primary and secondary theories, foundation and superstructure, main outlines and specific details. The secondary and usually more picturesque concepts ride, as it were, on the underlying primary principles, the latter being often taken for granted almost unconsciously because of long familiarity. It is almost characteristic of these secondary theories that they serve to improve the representation of nature in particular aspects, act as correction terms, so to speak, in their respective places of usefulness. They prove serviceable so long as they are nearly enough in harmony with the primary principles and are fertile in suggestions for experiment and in means of amplified control of observed relations. But they

are usually too specific, gratuitously rich in picturesque detail, and there come times when, because of inadequacy of the primary structure, these secondary concepts are stretched so far as to interfere with each other or come into conflict with the basic principles, thus leading to confusion of meanings and bewildering uncertainty as to what is fact and what is fancy. The relativity ideas emerged when there was a plain need for some radical improvement in primary theory, in view of the dilemma of the ether and absolute motion. We are now in the presence of another such dilemma in the physics of light and electron-quantum relations and it has already been demonstrated that the relativity program has resources for this new task as well.

To be sure, the listing of any particular set of ideas as primary or secondary in the sense used is neither precise nor permanent. During the growth of a science there can usually be traced a steady progress of its concepts from the picture stage toward greater abstractness and generality. Einstein's scheme, however, came as fruition of a long period of development in a mature science, and considered by itself had from its beginning the form of a primary theory of specially comprehensive type. But the full history of such ideas really goes back to the dawn of science. We are now reading the latest chapter of the long story of geometry, mechanics and electrical theory, and are entering an epoch when these will be joined with chemical theory in a single time-space geometry.

We are now familiar with the important distinction between logical geometry, which is pure mathematics, and concrete geometry, which is really a field of experimental physics. It seems wise to keep steadily in mind the similar dual aspect of all physical theories. Every such has an abstract logical framework, which by itself is in the main mathematical, though frequently only informally arranged. It becomes a physical theory by the addition of a scheme of instrumental interpretations whereby a correspondence is indicated between the abstract terms and the language of experiment, so that observed relations can be compared with those implied in the theory. Changes in theory may relate to either item, and normally there is steady mutual influence. It is readily seen then why, according to the placing of emphasis, theories may be and have been viewed in such manifold ways, for example, as logical systems merely suggested by experiment, as sources of suggestion for experiment, as origins of predictions concerning the outcome of new experiments, as statements of "objective reality" adhered to with a tenacity not easy to understand.

For to-day let me emphasize a sort of intermediate view, according to which we may understand that, by a combination of an abstract chain of ideas with a scheme of instrumental meanings, a theory defines a system of expectations, equipped with which we essay the task of arranging and interpreting our observations. We like to say that a theory is to this extent true, that findings agree with expectations. But whether this occurs or not, it is standard practice to report the results of experiment by comparison with expectations, by giving residuals between measured and computed values, for instance. Moreover, the residuals in successful cases are merely small, not exactly zero, and there is even much arbitrariness in the meaning of smallness because of freedom of choice in the mode of scaling or plotting.

For this purpose, of supplying a standard of comparison and a terminology for communication, it seems not so important that a theory should be "true" as that it should be definite. No matter how large the residuals may be, the measured data may be justly describable in terms of them, provided the theoretical values used for comparison are really unambiguously determinate. Uncertainty may arise, either because suitable logical inferences have not been properly made, or because the intended experimental meanings of the abstract terms are not clear enough. When Einstein found a way out of the ether dilemma by giving an enriched meaning to the relativity of motion he uncovered an actual experimental ambiguity in the meaning of the time-scale, even in connection with so elementary a matter as the simultaneity of two spatially separated events. We now see that previous confidence in an absolute time-reckoning was connected with a risky extrapolation from the facts of experience, since science was not yet in possession of a method of transmitting signals with infinite speed, or of any other method of testing the synchronism of separated time-pieces so as to determine uniquely the required reduction of their readings to the alleged absolute scale. The time-scales of the new theory, relative to particular frames of reference, have a really improved directness of experimental setting. It is simpler to think of adjusting clocks to a domestic symmetry of readings in the case of to-and-fro signals in a moving system than to seek the particular departure from symmetry required in order to match some foreign scale.

Viewed in the way suggested a theory may seem to have fundamental values quite distinct from the mere matter of success in defining expectations which turn out to agree completely with findings. In fact, no theory has ever had such perfect success, though the Newtonian celestial mechanics reached a striking approximation to it; and no theory has ever been discarded merely because the residuals were not zero, although, to be sure, if they are uncomfortably large we look for a new theory to improve our expectations.

The relativity plan is then to take the FitzGerald contraction as the normal behavior of a body set in motion, with the understanding that a different outcome is to be explained by some added special condition. Similarly, a fixity of the fringes in the revolving interferometer is a standard of reference; and any observed shift is to be taken, not as discrediting the primary theory, but as something which this theory leaves to be interpreted by some superposed theory. Ideal solar wave-lengths, displaced according to Einstein's formula, are suggested as origins from which to estimate the departures due to such special conditions in the source as are not defined in terms of the primary space-time geometry alone. These are only a few of the many instances of altered standards suggested by the relativity theory, all closely knit and interlocked in the most comprehensive and strongly unified synthesis of physical theory yet reached. It is also to be remembered that there is a large range of phenomena that now come under sufficiently exact control by the primary theory itself, while they were formerly treated by more special devices. It would take a long time to give an adequate account of these cases. In the main it has surely been the habit of science to test theories of large scope as working methods or as systems of scientific thinking rather than by the results of individual supposedly crucial experiments.

In spite of some apparent strangeness in the newer ideas, their roots lie deep in the past, and if approached with sufficient historical setting are seen to be abundantly natural developments from some of the most vital things in previous science. To outline such a survey of this recent synthesis let us look at a few items of prerelativity physics, partly respecting their actual place in history and partly for brevity by way of an imaginary personal revision of some basal thoughts and experiments.

If we should make some straight-edges by sighting or triple matching, use them as guides in planing a drawing-board flat, mark off scales by firmly constructed dividers, then survey a great variety of drawings, we should likely, after much trial and disappointment possibly, be able to codify something much like practical Euclidean geometry and to idealize it into an abstract system as well. Then furnished with this system, if we should by sighting mark what we would call straight scratches on a frozen pond, lay off isosceles triangles and so on, and measure separations by stretched tapes, we should find that the surface of the ice so observed very closely met a natural and intelligible expectation that it would be found flat in the sense of the adopted geometry. If then we were able to go to much greater distances we would naturally harbor the *a priori* supposition that in a smoothed-off sense the whole earth would prove to be flat. Perhaps we might insist that it must be, because the pond was found to be.

But to proceed scientifically with a special problem, suppose we lay off equal large radial distances from home, measure the distance around on each locus so fixed, and tabulate the numbers so as to confront them with the expected linear relation $c = 2\pi r$. We find that observed drops below computed relatively more and more the larger the radius. If by this time we have acquired also the ideal three-dimensional Euclidean geometry in sufficient development, as we may have been led to do by experience with building construction say, and especially if we are convinced of the wisdom of geometrizing our experimental results when we can find a way, we change our expectations, and perhaps try a sine-curve, as belonging to a special curved surface whose ideal properties are familiar. But if the "flat" notion of the earth is not of our own making but rather traditional for many generations and habitually used in speculations, we may insist on plotting geographic places on a flat map and seeking a "physical" explanation of the regular "expansion" of the measuring tape when laid transverse to a beeline leading home. One wonders what the early course of world geometry would have been if we were giants living on a planetoid so small that we could walk around it before breakfast. Perhaps it is not really strange that we pygmies chained to a single planet are slow to reconsider our long-standing insistence on a flat space for the universe of stars.

A further example is at hand in the same connection. When we make explorations in three dimensions, to compare with the ideals of our space-geometry, we find on closer inspection that measuring-rods which agree when held horizontally do not agree when held vertically, when pressed on, or taken near a fire. We do not, however, abrogate our ideal geometry as a physical theory, but superpose on it a systematic experimental and mathematical study of what we call elasticity, and thermal expansion, using perhaps mystical language but really building a rational scheme that appears as a suitable extension of what we had called geometry.

To continue our studies so as to include motions of various objects, we construct as preparation certain periodic mechanisms to exhibit as consistently as we can a concrete parallel to our instinctive notion of a time-sequence, perhaps even noticing that in a mathematical sense we are adding a new and initially apparently independent geometry of one dimension. First we send various objects sliding over the skating-rink, and find that when nothing else is observed to interfere they move nearly along our straight scratches and reel off distances nearly proportional to the number of clock-beats. We therefore adopt a first law of motion defining a norm for horizontal

motions, then find that we can correlate departures with interferences by pushes, pulls, bumps, under the general heading of force. Then, knowing already what we mean by straight lines and distances in three dimensions, we formulate the three-space analogue of our first law and expect that projectiles while free from interference will behave approximately in the way defined. The results are widely different from the expectations.

Galileo tells us we can think of the projectile as moving with constant speed along its initial straight line, provided we add the idea that the line is thought of as dropping in a certain regular way, the same for all cases, thus clearly foreshadowing the Einstein principle of equivalence. Newton shows us how to arrange a mathematical account of the types of departure from our expectations, even in the much more extensive case of the solar system; tells us we can save our faces by speaking of a mystical force of gravitation or attraction, but warns us not to prefer hypothesis to rational system. Ignoring this warning our successors actually make hundreds of mechanistic hypotheses during the next two centuries, adding nothing to any real control of the matter. Then Einstein shows that we could have accounted for the whole of the large residuals from our first law ideal by simply reinterpreting that ideal in connection with a more generous geometry, by improving our mechanical geometry in much the same way though more complicated as that in which we had already improved our geographic geometry.

And now, dropping our play-acting and turning to our own century, let us glance at some of the things that have happened. The Newtonian mechanics has been extended to cover wide ranges of special phenomena by fuller and more precise development of its original principles. An extension to a supposed structure of matter, too fine to be surveyed directly, has led through an elementary kinetic theory of matter to the realm of general statistical mechanics, rich in bright lights and deep shadows. Other residual phenomena, some very striking, have been codified more or less separately under electrical theory, and this has absorbed the bulk of working ideas in the interpretation of light, so far as something more specific than a general wave-theory has been felt to be needed in optics.

Electrical theory was first modelled after a Newtonian pattern, but for some time its main outlines have been those drawn on an essentially independent plan by Maxwell. Since Minkowski's paper of eighteen years ago we can see that the real first step in the passage from Newtonian to Einsteinian relativity was taken by Maxwell when he introduced into his equations the term representing dielectric displacement current, since this rounded out what we may now call the isotropic form of these equations in time-space four dimensions.[2] But this was noticed only later, found out partly step-by-step by Lorentz and others, when in their labors on the pressing problem of the electro-mechanics of moving bodies they worked their way up to the now famous transformation from "ether" coordinates to others better suited for use in a moving system.

The new variables were first introduced merely as a mathematical device. The present era of relativity then got its full start when Einstein gave his simple experimental interpretation of the transformation, showed that all such systems of variables really belonged on a par with each other to a kind of democracy of systems of reference, and founded an improved kinematics free from the perplexities that had been specially noticed in the earlier blend of mechanics and ether physics.

The essential character of the new scheme was made clearer by the work of the next few years, led by Minkowski's mathematical revision. The germ latent in Maxwell's equations grew into a full-fledged time-space geometry and vector analysis, which exhibited the original transformation of variables as accompanying a change of axes or vectors of reference, with the components of electric and magnetic field vectors acting like area projections. By virtue of analogies with ordinary geometry and in other ways the results threw new light on the physical relations gathered by preceding science. Practically all main features of earlier physical theories proved to be adaptable, mostly with trivial changes if any, to the new scheme of arrangement, which was not only more perspicuous and better unified, but supplied a finer and more complete tabulation of the concepts and relations that had emerged during the long history of physical measurements. Thus to survey the new scheme fully would be to make a treatise on theoretical physics altogether. I want to dwell on one feature that has a general bearing on the relativity motive in scientific thinking and a particular bearing on the curvature theory of gravitation.

Like Euclid's geometry, like ordinary vector analysis and the far-reaching Ausdehnungslehre of Grassmann, now renamed tensor algebra, like such mathematical systems as the theory of invariants, the space-time vector analysis owes its simplicity to its direct attention to certain central concepts rather than to the partial and manifold representations obtainable by arbitrary modes of dissection. Time and space intervals are projections of a single vector, electric and magnetic intensities are components of a single

[2] It is noteworthy that this very item in Maxwell's scheme which led toward the relativity geometry is also the one which led to the notion of electrical waves and the later developments in wireless transmission.

property of the field, and like these examples the multiplicity of physical quantities appear as parts or components of a smaller set of basal properties. We recognize that a part of the complexity of our science can be understood as due to the manifoldness of the possible modes of partial representation or projection. This idea goes further than merely to cover the many cases so representable by coordinate analysis in the narrower sense. Thus time-lag, aberration, Döppler effect, are individual phases of the relation of a monochromatic source to the observer, and are separated only when an arbitrary though useful disjointing is carried out. We thus have a much more elaborate example of the same kind of simplicity as that which appeared in the study of the nebulae when it was pointed out that the variety of observed forms might correspond to various orientations of fewer intrinsic types.

Still, in the scheme of 1905–1908 a limitation was manifest which the spirit of the new theory itself made to appear rather artificial. The interpretation was limited to the comparison of frames of reference moving uniformly with respect to each other. Moreover, the physical mystery of gravitation remained essentially as Newton left it, together with the apparent absoluteness of rotation. Einstein guessed that these items belonged together. For it is clear that a more generous scheme would involve not only a relativity of direction and speed, but of straightness and of acceleration, and therefore some kind of relativity in the estimation of a gravitational field. A sweeping extension was thus conceivable, and a guiding principle was at hand.

Since Newton's time it had been customary to think of an observed gravitational acceleration as partly true attraction, partly centrifugal, but this might be another of the arbitrary dissections spoken of, and so it proved. This idea yielded the famous principle of equivalence which led to the goal sought, although it is not now recognized either as a permanent postulate or as a strictly correct proposition in the wider forms of the definitive theory. To the mathematical framework of this generalized theory of relativity and gravitation reference will be made shortly. The special results concerned with the planet Mercury, eclipse stars and spectrum shift are familiar. It is naturally out of the question to put such a large scheme of ideas into purely illustrative form, but various special examples are readily at hand, using rotating discs, falling elevators, and the like. The main idea may be described as the substitution of a wisely chosen curved space-time map for the previous flat one.

The curvatures introduced are such as to allow the exhibition of the planetary motions as instances of the first law of motion alone, to allow the definition in terms of curvature of all the general concepts of mechanics, and the deduction, as purely geometric theorems, of the general mechanical laws. With the actual data for planets and terrestrial objects the curvatures required are so minute as perhaps to seem strangely unpromising for such a sweeping extension of the powers of geometry as a physical theory. But herein lies the explanation of two prominent items; first, why such a simple scheme as Newton's could give such accurate results, second, why these curvatures are open to theoretical use for the purpose without being subject to challenge by direct test, since only the most precise geodesy could hope to detect the disparity between old and new estimates of intervals by length and time measurements alone.

There is to be seen here a fresh instance of a procedure widespread in scientific method, which may be called magnification by indirection. We may like to define a straight segment as the shortest path between two points, but we know that the test of straightness by sighting is vastly more delicate in practice. The vernier, the slow beats between rapid vibrations, interference measurements, stroboscopic devices, colored indicators, are a few from the myriad of examples. Einstein's identification of mass and energy gives another, according to which the processes of calorimetry may be thought of as yielding highly magnified symptoms of minute changes of inertia. These cases suggest a certain general motive of thought that seems likely to be of enduring importance and give hints of further power that may be latent in world geometry.

The instrumental method whereby some feature of nature is first revealed as admitting quantitative examination is usually crude in comparison with the means later found for its detailed analysis and measurement. The discovery of a phenomenon of some novelty is commonly followed by a systematic search for improvements in technique whereby its details can be magnified in some sense for accurate estimation and inspection. The two examples given from the relativity theory of mechanics illustrate a kind of theoretical analogue of this experimental procedure and suggest something of its further possibilities when combined with the resources that mathematics has to place at the disposal of physical theory for the purpose of representing measurements that are necessarily of limited precision or resolving power.

According to the new interpretation curvatures so minute as to escape detection by direct length measurements serve for representing all phenomena open to what have long been called mechanical experiments, while the latter are still not precise enough to show the delicate mass changes with which calorimetry deals rather accurately under another name. Since optical phenomena are in the main still more delicate it is

not surprising that correspondingly delicate details in the geometry should suffice to give at least a partial representation of light in a way that seems to promise complete removal of the traditional dualism between matter and radiation in energy relations. Not only is the black body problem thus given a new setting, but it seems practically certain that when the needed revision is carried out the entire realm of thermodynamics will prove to be geometrically interpretable in the time-space manifold. Clearly, in our present physico-chemical thermodynamics it seems vital that increments of heat, of work, of matter of various kinds should be distinguishable in some unambiguous way. If they are all to be interpreted as mass changes, the distinction may turn out to be another of the artificial dissections spoken of above.

This suggested identification of mass and energy is a central feature in the new mechanics and supplies a rather ironical comment on the earlier history of the theory of heat, when the conservation of energy was understood as a substitute for the caloric theory. It is the beginning of a needed reconsideration of the relation of thermal and mechanical concepts, which will include an interpretation, suitable for the relativity scheme, of the various kinds of matter recognized as distinguishable by the phase rule. Thermodynamics has thus far received unduly little attention under the relativity program, and some of the few adjustments already proposed seem unlikely to remain satisfactory. Thus, since entropy has been commonly taken as an extensive quantity associated with a three-dimensional volume, it is not natural that it should appear as a four-space invariant. The relativizing of physical probability remains to be undertaken, but on account of the close connection with molecular physics we may notice two ways in which the perplexing subject of statistical mechanics is likely to be clarified.

First, the characteristic postulates of this subject, particularly those clustering about the troublesome ergodic hypothesis, are plainly conditioned by the aloofness of the time-scale and serve mainly to introduce into the statistical treatment of motions, especially of irreversible processes, something of the kind of dynamical determinism that was so prominent in the Newtonian mechanics. In the unified kinematic geometry it should be possible to replace these postulates by mathematical definitions and theorems and thus remove some of the faults that have hitherto been felt to be personal to this subject. Second, it seems likely that, in the light of relative time, the property of irreversibility may prove to be relative to particular modes of projection rather than intrinsic to the space-time configuration, hence possibly not justifying the sweeping consequences often insisted on in connection with the second law. Moreover, a really satisfactory solution of these questions would cover the thermodynamics of radiation, and the fact that the quantum hypothesis had a statistical origin is one reason for expecting that relativity should place the quantum problem in a new light.

Although its fine-structure theory is a significant exception, the quantum theory has in the main proceeded independently of the relativity revision. It is therefore not surprising that a reconsideration of the quantum phenomena from the point of view of a general world geometry should indicate the possibility of reinterpretation without the quantum hypothesis. It has in fact been found that under a proposed interpretation of light, using an enriched and adapted form of wave-theory, a difference-structure in spectrum relations would be present, and that the Einstein quantum relation of voltage and frequency is a corollary of the difference-structure and the relativity of the time-scales. The apparent necessity for a really novel type of discontinuity disappears and a close affiliation with "classical" theories is restored.

But even ignoring special problems we may see that the astronomical side of relativity should have a natural counterpart in molecular physics, since the arbitrary outward extension of the Euclidean geometry assumed during two centuries of celestial mechanics has long been matched by its inward extension or interpolation for the representation of the fine structure of matter. The important meaning now known for curvatures affecting the mutual relations of distances like 10^{13} centimeters may well be matched by a far-reaching significance in curvatures affecting distances like 10^{-13} centimeter. There are abundant reasons for expecting that in the not distant future the whole of electrical and optical theory and a rational physico-chemical theory of the varieties of matter will be aspects of a fine-scaled time-space geometry. To exhibit one feature of this outlook of special interest for chemical theories let us notice one striking fact about the mathematical side of the Einstein movement.

The earlier Greek geometry grew in close contact with concrete experience, but it was later systematized in more abstract form, and thus furnished the first great example of a highly developed mathematical theory, cultivated partly for its own intrinsic interest. When Kepler reviewed the planetary kinematics he found the deductive geometry of the conic sections awaiting the wide range of physical applications later gathered. Then, roughly speaking from Newton to Fourier, there followed an epoch when mathematics and physical theory grew for the most part together, quite largely under the same leaders; with germs of mathematical principles arising in physical problems and their developments reacting on physical theories. This process has continued, but for about a century

past there has been discernible a considerable degree of separateness, with only a minority of the leaders effective in both respects. During this period of intense cultivation of pure mathematics for its own sake a number of mathematical systems grew to high stature in advance of any but elementary contact with experimental science. Among these is the Riemann geometry and its associated general calculus, unwisely named "absolute," which was elaborated some time before Einstein found his remarkable physical interpretation for the four-dimensional case, although Riemann and Clifford foresaw something of the possible physical meaning of curvature. Thus, in contrast with the Newtonian system, the Einstein mechanics found its natural mathematical machinery already highly perfected. In a more general philosophical sense it may be remarked that the postulational movement in abstract mathematics represents a kind of relativity movement, with its reaction on the concrete sciences just beginning. There will be other examples like the Riemann-Einstein of anticipation and fruition, and in particular if time permitted it could be pointed out how some of the existing fields of mathematics seem peculiarly adapted to the special needs of chemistry, though their possible value in this way is only meagerly appreciated.

This same epoch of independent mathematics has witnessed a great increase in the variety of physico-chemical phenomena experimentally studied and the variety of measurements and technical devices used in their exploration. But chemistry is still only approaching the stage of mathematical formulation, and in both sciences there has been a marked growth in the relative prominence not only of what have been called secondary theories but of shadowy notions, mystical hypotheses and vague analogies. The art of the experimenter has outrun the vision of the logical physical theorist, while pure mathematics, not keeping such fullness of contact with its concrete origins, has been discovering more consciously its own natural character and powers. But the new wealth of experimental knowledge may become a bewildering burden if its theoretical counterpart remains too much a maze of special and even partly contradictory hypotheses. It is needful that a wider range of experimental results be brought under control by simple and comprehensive primary theory, and there is now a wealth of mathematical material at hand for the purpose. The world geometry has made one great stride in this direction and opened other paths just beginning to be followed. It is clearly desirable that the promise and power of its way of thinking should not be masked by undue emphasis on its relation to special experiments.

A. C. LUNN

THE UNIVERSITY OF CHICAGO

MYSTERIOUS ACOUSTIC PHENOMENA IN YELLOWSTONE NATIONAL PARK

IT is highly gratifying that the American people are making yearly increasing use of the Yellowstone National Park and that each season many thousands become for the first time acquainted with its beauties and wonders. Among future visitors there will be some who will experience the strange and bewildering musical sounds that for many years have been noted in certain parts of the park. As a partial contribution to the solution of the mystery, a personal observation on one manifestation of the weird phenomena may be of interest.

This subject has received scant mention in various published reports and articles, and by some people has been relegated to the category of yarns and myths which helped to make Jim Bridger famous. The best account seems to be that contained in the best work[1] on the park, that of General Chittenden, from which the following quotation is taken (pages 288-289):

> A most singular and interesting acoustic phenomenon of this region, although rarely noticed by tourists, is the occurrence of strange and indefinable overhead sounds. They have long been noted by explorers, but only in the vicinity of Shoshone and Yellowstone Lakes. They seem to occur in the morning and to last only for a moment. They have an apparent motion through the air, the general direction noted by writers being from north to south. They resemble the ringing of telegraph wires or the humming of a swarm of bees, beginning softly in the distance, growing rapidly plainer until directly overhead, and then fading as rapidly in the opposite direction. Although this phenomenon has been made the subject of scientific study, no rational explanation of it has ever been advanced. Its weird character is in keeping with its strange surroundings. In other lands and times it would have been an object of superstitious reverence or dread and would have found a permanent place in the traditions of the people.

In the summer of 1919, during a visit to the park in connection with governmental fish-cultural and fish-planting work therein, the present writer, in company with Mr. A. H. Dinsmore, of St. Johnsbury, Vermont (a former superintendent of fish hatcheries in the park), made a camping trip to Lewis and Shoshone Lakes, employing pack horses, with helper, and having as a part of the equipment an Oldtown canoe transported by motor truck from Yellowstone Lake to Lewis Lake.

About eight o'clock on the morning of July 30, after having camped for two days and two nights on the shore of Shoshone Lake at its outlet at the

[1] "The Yellowstone National Park," by Hiram Martin Chittenden. New and enlarged edition. Cincinnati, 1915.

southern end, we entered the canoe and pushed off from the shingly beach, headed for the northern end of the lake. The surface of the lake was glassy, the air was still, a faint haze overhung the water, the sky was cloudless, and the lake for a considerable distance out was in the shadow of heavily timbered hills. The canoe had barely gotten under way and was not more than twenty meters from the shore when there suddenly arose a musical sound of rare sweetness, rich timbre, and full volume, whose effect was increased by the noiseless surroundings. The sound appeared to come from directly overhead, and both of us at the same moment instinctively glanced upward; each afterward asserted that so great was his astonishment that he was almost prepared to see a pipe organ suspended in midair. The sound, by the most perfect gradation, increased in volume and pitch, reaching its climax a few seconds after the paddling of the canoe was involuntarily suspended; and then, rapidly growing fainter and diminishing in pitch, it seemed to pass away toward the south. The sound lasted ten to fifteen seconds and was subsequently adjudged to range in pitch approximately from a little below center C to a little above tenor C of the pianoforte, the tones blending in the most perfect chromatic scale.

It was at once realized that this was probably a manifestation of the strange phenomena referred to by General Chittenden, whose book had been read in camp, and that an opportunity was presented to investigate and perhaps elucidate the mystery. So favorable was the opportunity that in a short time we were reproducing the sound at will.

Following the dying away of the music and the short period in which we were held spellbound, paddling was resumed and, as the canoe gained sufficient headway, the music recurred in practically the same form as at first, and, as the paddling ceased and the momentum of the canoe fell off, the sound died away. It was then perceived that the sound was coincident with the motion of the canoe: when a certain speed was reached and maintained, the sound was produced and maintained; before that speed was attained there was no sound, and after that speed was lost the sound ceased.

A search for the cause of the sound disclosed the following situation: A jointed bamboo salmon rod with its butt-end touching the side of the canoe was projecting backward about half a meter beyond the gunwale; the waxed silk line was reeled in, but about a meter of line with the lure at the end was wrapped several times around the terminal joint; a lead sinker weighing one hundred grams, that had been attached in order to carry the lure into deep water frequented by the large trout with which the lake had been stocked, was dangling from the end of the rod about five centimeters below the surface of the water. As the canoe moved through the water, the short length of free line, held taut by the sinker, rapidly vibrated in conformity with the speed of the boat; the vibrations were transmitted through the bamboo rod to the canoe, whose thin, curved, rigid sides and bottom acted as a sounding board and gave out an augmented volume of sound that seemed to be concentrated or focused overhead. The combination of essential factors present in this case seems to have been a smooth water surface, a vibrating cord, a resonant body to which the vibrations were transferred, and still air, with perhaps other favorable atmospheric conditions. Later, in other parts of the lake, where the surface was disturbed by ripples or waves and there was slight to moderate movement of the air, attempts to reproduce the sound were futile, although the other factors were as in the original manifestation.

It is not to be inferred that the conditions and explanation herein given are held to account for all the mysterious musical sounds that have been heard in the park. On the contrary, owing to the rarity of the occasions when canoes had been used in park waters, it seems likely that the exact combination of factors noted must have been exceptional. All that is claimed for this manifestation is that it fulfilled the requirements of the mystery as described by the best observers and that its cause was ascertained. An account of the occurrence was promptly given to the superintendent of the park.

That acoustic conditions on Shoshone Lake that morning may have been peculiar is suggested by another observation as the canoe was skirting the eastern shore of the lake and the Shoshone Geyser Basin came within visual range. During several of the eruptions of the principal geyser, the splashing of the geyser water on the hard siliceous platform was distinctly heard. The distance in an air line, according to the official Geological Survey map, was approximately nine kilometers.

HUGH M. SMITH

BANGKOK, SIAM

SIR JOHN BURCHMORE HARRISON

WITH the recent announcement in SCIENCE of the death on February 8 of Sir John B. Harrison, director of the department of science and agriculture in British Guiana, it is fitting that some reference should be made to the career of this distinguished chemist, whose work is unfortunately too little known to American scientists.

John Burchmore Harrison was born at Birmingham, England, on May 29, 1856, and received his preliminary education at the Edgbarton Proprietary School, after which he became a student in Christ's College,

Cambridge. In these years of preparation young Harrison came under the influence of such teachers as Gore, Liveing and Dewar, who laid great stress upon the ability of students to devise their own methods and apparatus according to the needs of each special case. The system then in vogue gave a well-rounded training in several sciences and in that power of correlation, which, as seen in such men as Darwin (also of Christ's College), has been the peculiar endowment of so many Cambridge alumni. At the age of twenty-two Harrison received his bachelor's degree, being Natural Science Scholar of his college. Following graduation he did research work in agricultural chemistry at Cambridge and also for a short time at the Rothamsted Experiment Station under Sir John Lawes and Sir Joseph Gilbert.

In 1879, Harrison began his life work in the tropics by accepting an appointment as professor of chemistry and agricultural science in Barbados. During this period, he and his associate, J. R. Bovell, began their famous experiments upon the development of new varieties of seedling sugar canes. The ancient custom of propagating the sugar cane by germination of the buds upon the stalk had led to a general belief, notwithstanding occasional reports to the contrary, that the seed, which is borne on a plume at the end of the cane, was sterile. But all doubts as to the fertility of sugar-cane seed were finally dispelled by the independent, and almost simultaneous, proof of the fact by Soltwedel in Java in 1887 and by Harrison and Bovell in Barbados in 1888.

In 1889 Harrison went from Barbados to British Guiana, where he accepted the appointment of government chemist and professor of chemistry. He was promoted in 1905 to the directorship of the department of science and agriculture, receiving also the appointment of government geologist—positions which he retained until his death. His arrival in British Guiana came at a most opportune time, for the old Bourbon variety of sugar cane, which was the colony's chief source of sugar, was succumbing to the attacks of fungus diseases. By introducing the new hardier seedlings which he had developed in Barbados, Harrison was able to save the sugar industry of British Guiana from extinction. The D–74 and D–95 varieties which he originated were afterwards introduced into Louisiana with most beneficial results. His researches upon the breeding and agriculture of sugar cane were continued until his death.

Harrison's field experiments upon tropical crops were controlled by most careful meteorological observations, such as air and soil temperatures, humidity, degree of sunshine, rate of evaporation and rainfall. He made very extensive investigations upon the composition of the salts removed from the atmosphere by rain and dew—a line of investigation in which he first became interested at Rothamsted.

Another important contribution which Professor Harrison made to the industrial advancement of British Guiana was his discovery of the famous bauxite deposits in the Christianburg-Akyma district of the Demerara River, while he was engaged upon a geological survey of this region in 1897. He devoted much attention to studying the origin of these deposits, which are the most extensive in the world, and attributed their formation to the decomposing action of carbonated waters upon diabase and other siliceous rocks. He conducted many geological expeditions in the West Indian Islands and in the interior of British Guiana, and for his work in this field was awarded the balance of the Wollaston Donation Fund in 1899 by the Geological Society of London. In addition to his study of the bauxite deposits he conducted surveys of the gold- and diamond-bearing areas of British Guiana. Among his numerous contributions to geology and mineralogy there should be mentioned also his recent discovery of a native alloy of palladium and mercury, a mineral hitherto unknown and of which a specimen was deposited by him in the National Museum at Washington.

In agricultural chemistry Professor Harrison is perhaps best known for his exhaustive investigations upon the formation and composition of tropical soils. His studies in this field are closely related to his work as a geologist, this coordination of activities leading to most brilliant results as in the similar case of the late Professor E. W. Hilgard in the United States. Harrison showed that, during the decomposition of the old silicate rocks by meteorological, chemical, physical and biological forces, the potassium, calcium and other elements essential to soil fertility were leached away and contributed to the agricultural richness of the alluvial low lands, while the sand, kaolin, bauxite and other residues, left on the uplands of British Guiana, gave rise to soils of comparatively low agricultural value. These studies of Harrison exploded some false ideas regarding the fertility of certain inland Demerara soils. Harrison's investigation of the rapid complex chemical changes, which take place in tropical soils as a result of oxidation, hydration and nitrification, have also been of great importance. These various researches upon soils required the correlation of many different sciences. Questions of geology, mineralogy, chemistry, physics, meteorology, biology and agriculture were all mutually involved, and the great value of Harrison's diversified scientific interests was shown more conspicuously here than in any other branch of his work. The comparative inaccessibility of certain publications of British Guiana has prevented many of his investigations in

this and other scientific fields from becoming more widely known.

Those who have had the good fortune to visit Sir John, either at his beautiful home in the Georgetown Botanical Gardens, or at his spacious, well-equipped laboratory, will recall with pleasure his cordial manner and delightful personality. The museum of "Mares' Nests," which he kept in his office, will never be forgotten by any one who has seen that famous collection of disappointed hopes. His rugged independence of opinion, his caustic comments upon false pretenses and his outspoken contempt for every kind of sham, although mistaken by some as indicative of pessimism, were only the evidences of his deep sincerity and love for truth. In later years he was blamed for an apparent unwillingness to share the growing responsibilities and burdens of his many-sided position with others, but his attitude in the matter was natural. Unassisted he had built up and coordinated the varied scientific activities of the colony into a single unit, and the relinquishment of any part of this work was to him almost like the disowning of a child. Owing to physical debilities Sir John was nevertheless upon the point of withdrawing from active work in order to spend the remaining years with his daughter in England, when his life was cut short only a few weeks before the date of retirement.

In addition to his duties as director of the department of science and agriculture and government geologist, Professor Harrison, at the time of his death, was chairman of the board of agriculture, chairman of the Sugar Planters Experiment Stations Committee, and a member of the Executive Council of the Colony. He maintained an active interest in American science, having visited the United States on various occasions and being a member of the American Association for the Advancement of Science, of the American Chemical Society and of the American Geological Society. He was the recipient of many honors, having received the order of C. M. G. in 1901 and the knighthood in 1921.

For variety, scope and economic value the thirty-seven years of Sir John Harrison's scientific work in British Guiana are without a parallel. There is no one man who can fill his position. Versatile, all-round investigators of his type are now no longer produced. The world of science is much poorer with his passing.

BUREAU OF CHEMISTRY C. A. BROWNE

SCIENTIFIC EVENTS

COOPERATION BETWEEN THE UNITED STATES AND GREAT BRITAIN IN MINE SAFETY RESEARCH

UNDER the program of cooperative research between the United States Bureau of Mines and the British Safety in Mines Research Board, Dr. H. F. Coward, an English investigator, well known for his researches on the ignition of gases and the propagation of gaseous explosions, is working at the Pittsburgh, Pa., mining experiment station of the Bureau of Mines, on a number of scientific problems connected with ignition and explosion of gases. G. W. Jones, E. J. Meiter, M. D. Hersey and H. P. Greenwald, of the Bureau of Mines Technical staff, have been assigned to work with Dr. Coward on the following problems:

The limits of inflammability of methane in air to which certain diluent gases have been added;
The ignition of gases by minimum flames;
The measurement of the pressure developed by gaseous explosions;
The propagation of flame in mixtures of gas and air.

Good progress has been made with each research, and the results will be embodied in joint publications of the Bureau of Mines and the Safety in Mines Research Board, according to the annual report recently made by Dr. R. V. Wheeler, in charge of the British mine safety research work and George S. Rice, chief mining engineer of the Bureau of Mines.

In exchange for Dr. Coward's services, Dr. R. Thiessen, of the Pittsburgh experiment station, has been in Sheffield, England, for some time assisting the Safety in Mines Research Board in its researches on the spontaneous combustion of coal and the inflammability of coal dust. Dr. Theissen was selected for this assignment because of his wide knowledge of the constitution of coal, to the study of which he has devoted many years while associated with the Bureau of Mines.

Arrangements have also been made, under the cooperative agreement, for the exchange of information on two particular groups of researches in which the experimental difficulties are great and the necessity for obtaining accurate information is pressing. These researches deal with the inflammability of coal dust and with the measurement of the degree of fineness of dust particles. The corresponding members of the two staffs are F. M. Bouton and A. Allison, of the U. S. Bureau of Mines, and E. F. Greig and A. L. Godbert, of the British Board.

As a result of a series of conferences held at the Pittsburgh experiment station, the following-named problems are being studied by the British and American organizations, simultaneously or by one or the other of the organizations separately, with a full exchange of information between the investigators concerned:

The composition of coal as affecting its inflammability.
The effect of the fineness of coal dust on its inflammability.

The effect of the character of the atmosphere on the ignition of coal dust. Chemical composition.
Miscellaneous sources of ignition of coal dust.
The obtaining of a measure of fineness of coal dust.
The efficacy of devices for arresting an explosion after it has traveled some distance. Rock dust barriers.
The behavior of different coal dusts as regards the propagation of flame.
Propagation with wetted coal dust.
The effect of the mode of deposition of dust on the ease of propagation of flame.
Ignition of firedamp by lamp flames. Addition of helium and chlorinated hydrocarbons.
The propagation of flame in mixtures of natural gas and air. Field work in large galleries.
The propagation of flame in mixtures of natural gas and air. Laboratory work.
The effect of partial distillation of coal on its oxidation.
Heat production during oxidation.
Underground communication.
The charge-limit gas-composition curve for explosives.
The composition of the products of detonation of explosives.
The effect of confinement and the nature of the tamping of the charge-limit of explosives.
Cushioned blasting.

THE ENDOWMENT COMMITTEE OF THE ENGINEERING FOUNDATION AND ENGINEERING SOCIETIES LIBRARY

AT the meeting of Engineering Foundation in New York on May 19, Mr. W. L. Saunders, president of the United Engineering Society, announced that, in response to a request from Engineering Foundation last December and repeated suggestions from the Founder Societies of Civil, Mining, Mechanical and Electrical Engineers, United Engineering Society had appointed an endowment committee to seek increase of funds for Engineering Foundation and Engineering Societies Library.

The personnel of this committee is made up of nominees of the four societies and other members as follows:

Ex Officiis: W. L. Saunders, president, United Engineering Society, *Chairman;* L. B. Stillwell, chairman, Engineering Foundation; Sydney H. Ball, chairman, Library Board.

Nominees of American Society of Civil Engineers: Charles F. Loweth, Chicago, chief engineer, Chicago, Milwaukee & St. Paul Railway; H. deB. Parsons, New York, consulting engineer; Ralph J. Reed, Los Angeles, chief engineer, Union Oil Company.

Nominees of American Institute of Mining and Metallurgical Engineers: D. W. Brunton, Denver, chairman, Board of Consulting Engineers, Moffatt Tunnel; J. V. N. Dorr, president, The Dorr Company (metallurgical, chemical and sanitary process equipment), New York; Thomas Robins, New York, president, Robins Conveying Belt Co., member, Naval Consulting Board.

Nominees of American Society of Mechanical Engineers: J. W. Lieb, New York, vice-president and general manager, The New York Edison Company; Wynne Meredith, San Francisco, member of firm, Sanderson and Porter; E. A. Simmons, New York, president, Simmons-Boardman Publishing Company.

Nominees of American Institute of Electrical Engineers: Calvert Townley, New York, assistant to president, Westinghouse Electric and Manufacturing Company; H. A. Lardner, vice-president, J. G. White Engineering Corporation, New York; E. Wilbur Rice, Jr., Schenectady, honorary chairman, General Electric Company.

Members-at-large: Charles F. Rand, New York, past-president, American Institute of Mining and Metallurgical Engineers; James H. Perkins, New York, president, The Farmers' Loan and Trust Company, financial adviser and custodian of securities for United Engineering Society; H. Hobart Porter, New York, of Sanderson and Porter, and president, American Water Works and Electric Company.

No hectic "drive" is planned, but an organization is being created to maintain a well-considered and persistent endeavor to get larger financial resources for Engineering Foundation and Engineering Societies Library as their opportunities for service develop.

The committee has had meetings and is studying plans for its work. Further announcements will be made later.

ALFRED D. FLINN,
Secretary

NATIONAL RESEARCH FELLOWSHIPS IN THE BIOLOGICAL SCIENCES

THE Board of National Research Fellowships in the Biological Sciences, at its last meeting on May 14 and 15, made the following additional appointments and reappointments for the year 1926–27:

REAPPOINTMENTS

L. Joseph Klotz—Botany
Helen Redfield—Zoology
Lewis E. Wehmeyer—Botany

NEW APPOINTMENTS

Theodora Mead Abel—Psychology
H. B. Adelmann—Zoology
Stuart Carter Dodd—Psychology
C. C. Epling—Botany
Carroll Lane Fenton—Paleontology
Dwight L. Hopkins—Biochemistry
Eugene M. Landis—Zoology
Margaret R. Murray—Zoology
R. H. Seashore—Psychology
George Gaylord Simpson—Paleontology
E. A. Swenson—Zoology
R. C. Travis—Psychology
G. C. Vaillant—Anthropology
A. M. Wolfson—Botany
Karl E. Zener—Psychology

The next meeting of the board for consideration of appointments will be held early in February, 1927. A more detailed announcement will be published in the fall. Applications may be received at any time for future consideration.

FRANK R. LILLIE,
Chairman

BOARD OF NATIONAL RESEARCH
FELLOWSHIPS IN THE
BIOLOGICAL SCIENCES

THE GOLDEN JUBILEE OF THE AMERICAN CHEMICAL SOCIETY

THE American Chemical Society was founded in 1876. It celebrates its fiftieth anniversary in Philadelphia from September 6 to 11, 1926. It is anticipated that some 3,500 chemists from all parts of the world will be present. The society will meet in eighteen divisional gatherings, as follows:

Agricultural and Food Chemistry
Biological Chemistry
Cellulose Chemistry
Chemical Education
Dye Chemistry
Fertilizer Chemistry
Gas and Fuel Chemistry
Industrial and Engineering Chemistry
Leather and Gelatin Chemistry
Medicinal Products Chemistry
Organic Chemistry
Petroleum Chemistry
Physical and Inorganic Chemistry
Rubber Chemistry
Sugar Chemistry
Water, Sewage and Sanitation Chemistry
History of Chemistry
Paint and Varnish Chemistry

Many of the divisions will hold special symposia of papers and addresses of importance from authorities in their respective fields. In addition, there will be two general meetings of the whole society with evening entertainments and gatherings open to all members and visitors.

The American Chemical Society will send no direct invitations or requests for the appointment of special delegates from other organizations. Instead, it publicly invites all non-American chemists to attend and take part in the meeting on the same basis and under the same conditions as members of the society.

The American Chemical Society is expecting many visiting chemists from other countries and will endeavor to see that they are given warm welcome in full fellowship at this gathering. Foreign chemists expecting to attend the meeting should, if possible, send advance information to Charles L. Parsons, Secretary, Mills Building, Washington, D. C., U. S. A.

SCIENTIFIC NOTES AND NEWS

THE degree of doctor of science was conferred at the recent commencement of Columbia University on Dr. Walter Sydney Adams and Dr. Max Mason. The recipients were presented by Dr. Michael I. Pupin, professor of electromechanics, and in conferring the degrees President Nicholas Murray Butler said: "Walter Sydney Adams—Born under foreign skies at ancient Athens; graduated from Dartmouth College with the class of 1898; astronomer and interpreter of celestial mechanics; director of the Mount Wilson Observatory at Pasadena; member of the National Academy of Sciences and its Draper medalist, as well as gold medalist of the Royal Astronomical Society, I gladly admit you to the degree of doctor of science in the university. Max Mason—A native of Wisconsin; graduated from its state university with the class of 1898; trained in advanced studies at the University of Göttingen; choosing the meeting point of mathematics and physics as a field of special intellectual interest and investigation and gaining marked achievement in it; called to high administrative office as president of the University of Chicago; member of the National Academy of Sciences, I gladly admit you to the degree of doctor of science in this university."

DR. IGNATZ MOSCICKI, professor of chemistry in the University of Lemberg, became president of Poland on June 5. Dr. Moscicki is reported, in the course of his address, to have said: "I am a new man in all political issues, and I shall have to inform myself before I take a stand on the various problems. I have the habit, as a scientist, and demand exact figures before I make decision, and if I am unable to do so on the moment I will confess it and tell the truth." Later in an interview he said: "I am a scientist but it will not hurt the country that politics is not being made a profession by me. We who serve the state should not be educated as politicians alone, but also as scientists and technicians. I can not divert my interest as a scientist, for the chemical question is one of the most important for my country and I will continue to be an adviser while serving the state loyally to the best of my ability."

PROFESSOR CHARLES SCHUCHERT has been elected an honorary member of the Kaiserliche Deutsche Akademie der Naturforscher zu Halle. This society, founded in 1652, now has 550 members, with the paleontologist and geologist Johannes Walther as its president.

DR. B. L. ROBINSON, Asa Gray professor of systematic botany at Harvard University, has been elected a corresponding member of the Botanical Society of

Geneva, Switzerland, in recognition of his services to the science of botany.

DR. CHARLES L. PARSONS, secretary of the American Chemical Society, has been elected an honorary member of the Societatei de chimie din Romania.

DR. JOHANNES SCHMIDT, director of the Carlsberg Laboratory in Copenhagen, was made an honorary member of the Washington Academy of Sciences on June 5.

THE University of Leeds will confer the honorary degree of D.Sc. upon Emeritus Professor P. F. Kendall, following professor of geology in the university.

THE University of Paris will next November confer the degree of doctor of laws on Dr. Carlos Chagas, chief of the public health service of Brazil.

PROFESSOR MAX FRIEDERICHSEN, director of the Geographical Institute in the University of Breslau, has been elected a corresponding member of the Finnish Geographical Society and also a member of the Academy of Natural Science in Halle.

PROFESSOR TREAT B. JOHNSON, of Yale, has been elected president of the American Institute of Chemists for the biennial term 1926–27; Dr. Lloyd Van Doren was reelected vice-president, L. R. Seidell was reelected secretary and C. K. Simon was reelected treasurer. Drs. William Walker, A. P. Sachs and R. E. Lee were elected councillors for three years.

DR. WILHELM SEGERBLOM, head of the department of chemistry at the Phillips Exeter Academy, has been elected president of the New Hampshire Academy of Science.

JOHN DORR BRADLEY, LL.B., has been elected president of the Chicago Geographic Society.

AT the twenty-second annual meeting of the American Society of Tropical Medicine held in Washington, D. C., May 28 and 29, 1926, the following officers were elected: Dr. George C. Shattuck, Harvard Medical School, *president;* Dr. Charles S. Butler, U. S. Navy, *first vice-president;* Dr. W. E. Deeks, United Fruit Company, *second vice-president;* Dr. Benjamin Schwartz, Bureau of Animal Industry, *secretary-treasurer;* Dr. Damaso Rivas, University of Pennsylvania, *assistant secretary;* Dr. G. R. Callender, U. S. Army, *councillor* for five years; Dr. Charles F. Craig, U. S. Army, senior editor of *The American Journal of Tropical Medicine.*

DR. JOHN O. SNYDER, professor of zoology at Stanford University, will leave for Woods Hole early in June to take his position as acting director of the United States Fish Commission Laboratory. Dr. Snyder will make a study of the larval life of certain marine fishes.

PROFESSOR J. A. FLEMING, who occupies the university chair of electrical engineering at University College, London, will retire on July 31 next; the senate has passed a resolution placing on record its sense of the importance of his achievements in this field of applied science.

A CORRESPONDENT writes: "The Russian physicists celebrated in Leningrad on May 16 half a century of activities of Orest Danilovitch Chwolson as a professor and scholar. The son of the late Professor D. A. Chwolson, the well-known Orientalist and Hebraist, he was born in 1852 in St. Petersburg (now Leningrad) and in 1876 was appointed lecturer in physics in the university of that city, and has since occupied that chair. His five volume manual on physics was translated into almost all European languages, and is recognized as the best text-book on physics in existence. The name of Professor Chwolson is especially known by his works in the domain of magnetism, dispersion of light and radiation. One of his recent contributions to the science of physics is an apparatus known as 'Chwolson's actinometer,' used for measuring the amount of energy which the earth receives from the sun."

DR. ROBERT M. OSLUND, assistant professor of physiology at the University of Illinois College of Medicine, will spend the summer visiting European laboratories and will attend the International Congress on Physiology at Stockholm.

AT the recent meeting of the Virginia Academy of Science, Dr. C. M. Sparrow, professor of physics at the University of Virginia, was appointed to represent the academy at the summer meeting of the British Association for the Advancement of Science.

DR. NEIL E. GORDON, head of the department of chemistry of the University of Maryland, and state chemist of Maryland, sailed on May 31 from New York for a European tour in the interest of chemical education.

DR. JOSEPH H. WHITE, of the International Health Board of the Rockefeller Foundation, has returned to New York from Brazil, where he has been conducting combative measures against yellow fever.

DR. J. STUART FOSTER, who has been an assistant professor of physics at McGill University since 1924, has been awarded a fellowship by the International Education Board and will go to Copenhagen to pursue researches on the Stark effect in association with Professor Niels Bohr.

PROFESSOR HAROLD S. BURR has been awarded one of the Sterling Senior Fellowships at Yale University for 1926–27. He will work on the comparative morphology of the nervous system in the laboratory of Dr. Kappers at the Brain Institute at Amsterdam.

AN Associated Press dispatch reports that Dr. Van Leeuwen, of Holland, has been made leader of the American-Dutch expedition which is in New Guinea exploring portions of the country not previously visited by white men and searching for pigmy tribes. The leadership was turned over to Dr. Van Leeuwen on the proposal of Professor Matthew W. Stirling, of the University of California, who originally was the head of the expedition.

DR. IVAN M. JOHNSTON has returned to the Gray Herbarium of Harvard University from a successful exploring expedition to northern Chile and adjacent Argentina. After several months spent in botanical collecting in the Atacama region, from the coast to the high passes of the Andes, Dr. Johnston went to Santiago and there devoted some weeks to an examination of the government herbaria, notably the collections of the Philippis, father and son. As a result, he brings to North America not merely his own copious collection from northern Chile, but many notes and photographs relating to the earlier botanical specimens secured in the same biologically interesting but little-known region.

ERNEST G. HOLT, of the section of ornithology in the Carnegie Museum, has returned from a collecting trip to British Honduras. His journey was made possible through the generosity of Messrs. Charles D. Armstrong and Mr. Herbert DuPuy. Mr. Holt succeeded in collecting material for a habitat-group representing the Red-footed Booby. On a brief excursion to Peten, Guatemala, he collected fine specimens of the Ocellated Turkey.

AN expedition will shortly leave New York to retraverse the trail of Theodore Roosevelt through the Brazilian jungles and down the River of Doubt. The expedition will be commanded by Mr. G. M. Dyott, an experienced South American explorer. Mr. Dyott has the support of the Roosevelt Memorial Association, which desires to complete a film record of the former president's travels. The party will consist of four whites, including two wireless operators to maintain contact with New York by a powerful wireless apparatus during its six months' absence from telegraphs.

DR. HARVEY CUSHING, professor of surgery at Harvard University, gave the principal address at the one hundred and first annual commencement of Jefferson Medical College.

MILO SMITH KETCHUM, dean of the college of engineering at the University of Illinois, delivered the principal address at the commencement exercises of the Colorado School of Mines, at Golden, May 21.

DR. WHEELER P. DAVEY, of the research laboratory of the General Electric Company, spoke on "What the Chemist can learn from Crystal Structure," at a meeting of the Central Pennsylvania Section of the American Chemical Society on May 18 and on May 20 before the Philadelphia Section.

A SERIES of lectures has been conducted by the Minnesota Chapter of Sigma Xi during the past year, from February to May, by Dr. Charles P. Berkey, of Columbia University, on "A Geologist's Story of the Gobi Desert"; Dr. A. H. R. Buller, of the University of Manitoba, on "Carnivorous Plants," and "Experiments on Sex in Mushrooms and Toadstools"; Dr. A. J. Carlson, of the University of Chicago, on the "Physiology and Functional Pathology of the Alimentary Canal" and "Problems in Endocrinology and Organotherapy"; Dr. A. E. Jenks, of the University of Minnesota, on "Known Facts concerning Prehistoric Man," and Dr. F. K. Richtmyer, of Cornell University, on "Seeing with X-rays."

DR. J. T. BOTTOMLEY, F.R.S., for many years Arnott and Thomson demonstrator in the University of Glasgow, and the author of researches and textbooks on dynamics and hydrostatics, died on May 18, aged eighty-one years.

SIR JAMES CANTLIE, the well-known London surgeon and specialist in tropical medicine, died on May 29 at the age of seventy-five.

THE death at the age of fifty-two years is announced of Dr. Otto Hecker, for many years head of the medical-optical division of the Karl Zeiss works in Jena.

VLADIMIR STECKLOW, a well-known mathematician and vice-president of the Russian Academy of Sciences, has died at the age of sixty-three years.

PROFESSOR L. A. HERDT, professor of electrical engineering at McGill University, Montreal, and president of the Canadian National Committee of the International Electro-technical Commission, has died at the age of fifty-three years.

AMELIA BRACKETT, botanical artist and taxonomist, died at Boston on May 31. A correspondent writes: "After graduation from Radcliffe College in 1920, Miss Brackett continued her botanical studies at the same institution, taking the master's degree in 1921 and carrying on investigations toward the doctor's degree. She has also been employed from time to time at the Harvard Botanic Garden as nomenclator, at the Gray Herbarium as artist and at the Arnold Arboretum as an assistant in the herbarium. In all these capacities she showed skill and ability. Her most noteworthy research work has related to the perplexing genus *Hypoxis*, of which her admirably illustrated revision gave the first clear treatment."

THE jubilee of the Association pour l'Avancement des Sciences will be celebrated at the 1926 congress of the association, which is to be held at Lyons from July 26 to 31. A large scientific exhibition has been organized in connection with the congress, with pharmacological, radiological, psychological and other medical sections.

THE Fourteenth International Geological Conference held its inaugural meeting on May 24 in the new hall of the Geological Institute. King Alfonso presided. Thirteen hundred delegates from all over the world were present in Madrid for the congress, which for purposes of work was divided into eleven sections. The Spanish committee responsible for the organization of the congress planned thirteen excursions to places of geological interest in the Peninsula, the Canaries, the Balearic Islands and North Morocco. The delegates also had an opportunity of visiting Toledo and the Escurial and were entertained by the Municipality and at the Royal Palace.

FORMER SENATOR JOSEPH S. FRELINGHUYSEN, of New Jersey, headed the American delegation to the International Conference of Experts on Oil Pollution of Navigable Waters, which met in Washington on June 8. Congress, in 1922, authorized the president to call a conference of maritime nations with a view to the adoption of effective means for the prevention of pollution of navigable waters. The use of oil as fuel by vessels and the evils that result, including pollution of bathing beaches, harbors and shore property, and the consequent detriment to property and health, shore recreation, increased fire hazard and injury to the fishing industry and wild life, were discussed. Plans for an agreement of maritime nations to control oil pollution have long been hoped for. The following countries indicated their acceptance of invitations to attend the conference: Belgium, Denmark, France, Germany, Great Britain, Greece, Italy, Japan, Netherlands, Norway, Spain and Sweden.

THE Sixth Congress of Industrial Chemistry will open at Brussels on September 17. This year the congress will be devoted to the leading chemical industries of Belgium, and the meeting will revolve around the six large permanent groups of the Société de Chimie Industrielle: I—Plant and Laboratory, II—Combustibles, III—Metallurgy and Mineral Industries, IV—Organic Industries, V—Agriculture and Agricultural Industries and VI—Economic Organization. In order to facilitate discussion these groups are subdivided into various sections. In order to take part in this meeting it will be necessary to be registered as a member of the congress. Registration cards may be obtained on request to the Secretary of the Congress, 65, rue du Canal, Brussels, Belgium. The delegates from the American Chemical Society are George W. Muhleman, professor of chemistry at Hamline University, and J. V. N. Dorr, of the Dorr Company.

CHEMISTRY'S developing influence in modern civilization will be a chief theme of the 1926 Conference of the Institute of Politics at Williamstown, Mass., according to an announcement by President James F. Norris, of the American Chemical Society. Leading men of science from the United States, Great Britain and the Continent will participate. The board of advisers of the Institute of Politics, Dr. Norris said, has unanimously adopted "The Rôle of Chemistry in the Future Affairs of the World" as the central topic for discussions, which will be organized and directed with the cooperation of the American Chemical Society. It is proposed to discuss such topics as future food supplies, energy (present and future sources and their utilization), chemistry in conservation, stressing wastes in industry and increased efficiency in production, synthetic *versus* natural products, chemical developments in their relation to labor, chemistry in world domination through commerce and in national defense and the relation of chemistry to world health.

A NEW catalogue of the British national collection of type cultures has been issued, which lists over 2,000 living strains of bacteria. The collection was under arrangement with the Lister Institute, where the collection is housed. Its object is the collection and maintenance of authentic strains of recognized bacteria and protozoa for use in scientific work. It includes both pathogenic organisms and strains of economic significance, while it has recently added cultures of fungi of importance in plant-pathology, medicine, veterinary science, technology and soil bacteriology. The staff are willing to help in the identification of strains received from workers both at home and abroad; and last year over 4,000 cultures were distributed to workers throughout the world.

UNIVERSITY AND EDUCATIONAL NOTES

IT is announced that the campaign fund of the New York Homeopathic Medical College and Flower Hospital has reached $500,000, of which sum Mrs. Stephen V. Harkness presented $100,000 for a department of physiology. Dr. Walter G. Crump also gave $60,000 for the equipment of this department. On June 2 the new college laboratory was dedicated and a statue of Dr. E. Guernsey Rankin, who died two years ago after serving Flower Hospital for many

years, was unveiled. Mrs. Harkness's gift of $100,000 was donated in memory of Dr. Rankin and the new department of physiology will be established in his name.

ROBERT LAW, JR., of New York, has given $80,000 to the development fund of the University of Chicago. The fund now amounts to $7,548,000, two million dollars having been contributed by the alumni.

THE late William Potter, president of Jefferson Medical College and Hospital, has bequeathed $50,000 in his will to the college.

JOHN D. ROCKEFELLER, JR., has given to the University of Strasbourg the sum of three and a half million francs for the enlargement of the nose and ear clinic and for the completion of various unfinished researches.

PROFESSOR ROSWELL C. GIBBS, of the department of physics at Cornell University, has been appointed acting dean of the College of Arts and Science during the absence on leave for the second term of Professor Robert M. Ogden.

DR. WHEELER P. DAVEY, for twelve years a member of the research laboratory of the General Electric Company, Schenectady, New York, has resigned to accept the professorship of physical chemistry at the Pennsylvania State College. He will have charge of instruction in physical chemistry and chemical physics, and will continue his researches in the nature of solids and liquids, crystalline and colloid. Dr. E. D. Ries, now instructor in the department of chemical engineering at the Massachusetts Institute of Technology, has been appointed associate professor of chemical engineering. Dr. Eugene Lorand, formerly technical adviser to the Anglo-Hungarian Bank at Budapest, Hungary, has been appointed assistant professor of industrial research.

ASSOCIATE PROFESSOR L. L. SMAIL, of the University of Texas, has been appointed to an associate professorship of mathematics at Lehigh University.

DR. GEORGE BACHMANN, professor of physiology in the School of Medicine of Emory University, has been offered the chair of physiology at the Jefferson Medical College of Philadelphia.

DR. F. M. ROWE, of the University of Manchester, has been elected to the chair of color chemistry and dyeing at the University of Oxford, from October 1 next, in succession to Professor A. G. Perkins.

PROFESSOR A. J. CLARK, professor of pharmacology in University College, London, has been chosen to succeed the late Professor A. R. Cushny in the chair of materia medica in the University of Edinburgh.

DISCUSSION

HUMAN TAILS

IN SCIENCE for April 2, 1926, I stated that I had discovered that the photograph of an Igorot with a tail, which I had published in my book on God and Evolution, was a fake, erroneously believed by me to be a genuine photograph. The sale of the book was immediately stopped. Two new photographs, unquestionably authentic, have been substituted and the book is again on sale. One is a case published by Professor Ross G. Harrison, of Yale, in the Johns Hopkins Bulletin for 1901, Volume 12, page 96. The other was first described in *La Naturaliste,* of Paris, for March 1, 1889, p. 53, being reported by Etienne Rabaud. It was reproduced in the *Scientific American,* Vol. LX, 1889, pp. 295 and 296. The use of the fake photograph is greatly to be regretted, though it's being false does not in the least affect my argument, as there are many genuine cases on record.

May I also add some other significant facts which speak loudly in proof of man's animal ancestry? With the exception of the kangaroo and the platypus, every mammal, from the lowest up to and including man, has a navel. The reason for this is that all mammalian embryos obtain from the mother's blood oxygen and food through the placenta (the after-birth), and also through the same medium get rid of the carbon dioxide and other noxious products of growth. A cord, the "navel-string," containing an artery and a vein, connects with the placenta at one end and enters into connection with the circulation of the embryo after passing through the navel.

Again, the very name "mammal" is derived from the breast or in Latin "mamma." In the female, the breasts provide food for the baby. In the male they are usually rudimentary. But note also two additional facts. In the male, not only is there always a nipple but in not a few cases, a real but imperfect breast exists, and is subject to the same diseases as is the normal female breast. For instance, I have operated in three case of cancer of the male breast. Many such cases have been reported.

Again there are seen not infrequently persons with super-numerary or extra nipples, occasionally with breasts behind the nipples. These may follow the double row of normal breasts, as seen for instance in a female dog, but very frequently they deviate considerably from the exact lines of the two rows. Many such cases have also been reported.

Such extra nipples and breasts may also be hereditary in both sexes. Hansemann mentions one case in which a father who possessed such extra nipples transmitted the same peculiarity to three of his sons

and two of his daughters. It would be very interesting to learn whether this peculiarity was passed on to his grandchildren.

Moreover, in the embryo in the very early weeks of its life, the lower end of the spine projects downward further than the legs. But soon the legs outgrow this effort to provide a tail and the end of the spine shrivels, leaving normally only the coccyx to remind us that all of us have had potential tails.

W. W. KEEN

PHILADELPHIA, PA.

CITATIONS OF SCIENTIFIC LITERATURE

WITH reference to the second question in Dr. E. G. Boring's letter in the issue of SCIENCE of April 30, 1926, may I give the results of my own experience—more in the use of than in giving literature references? As the result of considerable bibliographic work on several branches of chemical literature, it seems to me highly desirable that the general order of a journal literature citation should be as follows:

(1) Name of the journal, abbreviated if it is a widely distributed and well-known publication; otherwise given in full.
(2) The year of publication.
(3) Series number, if any.
(4) Volume number, or corresponding designation (as Jahrgang), in bold face type.
(5) Page numbers, or number of issue. Trade publications sometimes offer difficulties here, owing to the absence of issue numbers, or the separate pagination of each sisue.

As an example, "*Bull. Soc. Chim.*, Paris, 1899, (3), **21**, 1073–75."

The chief reason for this arrangement is that in libraries the bound volumes of journals are arranged in the order of the years of publication, and much confusion in locating the proper volume may be introduced if either the year or series number has been omitted, and especially when both have been omitted, as occasionally occurs. The problem is somewhat simpler, of course, in the more numerous publications which do not publish their volumes in separate series.

While the late Professor Joseph H. Kastle was at the Hygienic Laboratory, in Washington, D. C., I looked up for him a great many references in the Library of the Surgeon-General's Office, and I was told by the attendants at the library that I would save them time if I would put the year immediately after the title of the journal on the request slips. I did not entirely realize the advantages of this arrangement at that time, but it has certainly been my experience since that for reference purposes it is the most convenient form. Placing the date after the volume number in the case of journals such as the *Berichte der deutschen chemischen Gesellschaft*, where the page numbers are frequently numerically equal to current years, has more than once resulted in the year being copied for a page number, with consequent loss of time and patience by an investigator who has to consult an index in another volume to correct his reference.

F. A. MCDERMOTT

CLAYMONT, DELAWARE

REPLYING to Boring's question (SCIENCE, April 30, 1926, p. 456) concerning the place of the date in a citation I may be allowed to state that there seem to be several good reasons why the date should be placed at the end of the citation and not intercalated between volume and page. The most weighty reason seems to me the danger that the date of publication may be confused with the year for which the volume is issued and which, if given, will have its rightful place after the volume, *e.g.*, Proc. Indiana Acad. Sci. **34** (1924) : 255 (1925), which means that vol. 34 contains the Proceedings for the year 1924, but was published in 1925; if the date of publication were following the volume, it would very likely be taken for the year for which the Proceedings were issued. Another reason is that the publication of a volume often extends over more than one year and that the date of publication in this case belongs properly to a certain number or part and as this is usually not mentioned in the citation, but is only indicated by the page, the date belongs to the page rather than to the volume. A third reason is that the date is not absolutely necessary to a clear citation and if given should not separate the essential parts which consist of volume and page in a periodical or work of several volumes.

ALFRED REHDER

ARNOLD ARBORETUM,
HARVARD UNIVERSITY

INTRODUCTION OF LEMMINGS ON ST. PAUL ISLAND, ALASKA

IN JUNE, 1925, a number of Pribilof lemmings (*Lemmus nigripes* True) were collected on St. George Island, Alaska, by the Bureau of Fisheries and transported to St. Paul Island by the U. S. Coast Guard cutter *Algonquin*. During the time that the animals were in captivity a number of young were born, but the record does not show that any of these survived. Six males and six females were liberated near Lake Hill Lake, St. Paul Island, on June 25. Subsequent observations showed that the animals had established runways and were apparently doing well.

This species of lemming is known only from St. George Island. On a number of previous occasions years ago specimens of these animals were brought

from St. George Island to St. Paul Island, but there is no evidence to show that they survived in their new habitat.

HENRY O'MALLEY

BUREAU OF FISHERIES,
WASHINGTON, D. C.

APROPOS THE "WHITE INDIANS" OF DARIEN

THE following is a quotation from Joseph Esquemeling, "The Buccaneers of America,"[1] Chapter XXV, published in 1699. Esquemeling is describing his own personal observations.

> We sailed from thence [Bocca del Toro] March 23, 1679, and in our way touched at the islands called Zambles. These islands reach eight leagues in length, lying fourteen leagues westward of the River Darien. Being here at an anchor, many of the Indians, both men and women, came to see us. . . . The men here go naked, . . . The men paint themselves sometimes with streaks of black, and the women with red: The women have in their noses a pretty thick ring of gold or silver, and cover themselves with a blanket only: they are generally well featured; *among whom I saw several fairer than the fairest of Europe, with hair as white as the finest flax; 'tis reported of them, that they see better in the dark than in the light.*[2]

MAYNARD M. METCALF
JOHNS HOPKINS UNIVERSITY

SCIENTIFIC BOOKS

Helmholtz's Treatise on Physiological Optics. English Translation from the Third German Edition. Edited by JAMES P. C. SOUTHALL. Volume II, "The Sensations of Vision," 1924, viii + 480 pp.; Volume III, "The Perceptions of Vision," 1925, x + 734 pp. Published by the Optical Society of America.

THE appearance of the third volume of the English translation of Helmholtz's great "Handbuch der physiologischen Optik" completes one of the most notable scientific publications of recent years. Helmholtz's "Optik" is a unique book from many angles. It is unique in the thoroughness with which it displays the versatility of the master scientific mind of the nineteenth century. It is unique in the completeness with which it summarizes and establishes the science of physiological optics. Even more, it is unique in its longevity; originally decades in advance of its times, its friends have not permitted it to grow old; they have dressed it in many new chapters and appendices and its original vigor has carried it on for seventy years. The present English translation, by Professor Southall, provides the English-reading public with something more than a newly intelligible classic; it offers an up-to-date compendium of the most fascinating branch of optics. In its field, Helmholtz's treatise has no rivals and is unlikely to have any for years to come. What modern scientist would dare to write a book like this, even if he were able to do so? What publisher would dare to print it as a commercial venture?

To review the contents of so classical a work seems supererogatory and anachronistic, yet there may be those to whom such a review may convey an impression which they had previously lacked. The first German edition appeared in three parts, during the years 1856, 1860 and 1866, respectively; forming *Band IX* of Gustav Karsten's "Algemeine Encylopädie der Physik." The work was combined into a single volume with the imprint of Leopold Voss, of Leipzig, in 1867. (The reviewer has a copy from the library of William James, marked "Dresden, June, 1868" and containing the personal cards of "Dr. Hermann von Helmholtz, Präsident der Physikalisch-Technischen Reichsanstalt. Berlin, 16. Neue Wilhelmstrasse," and "Frau von Helmholtz geb. von Mohl.") A translation into French was published in 1867. A second German edition began to appear in 1885 but was not completed until after the death of Helmholtz, which occurred in 1894. As a single volume, under the editorship of Arthur König, it was published by Voss in 1896. This edition had been extensively revised and brought up to date by Helmholtz and König. It met with less favor from critics than did the first edition, and when Gullstrand, von Kries and Nagel prepared the third German edition (1909–1911), they based it upon the original text.

The present English translation is from the third German edition. It offers all the detailed appendices which were added by Gullstrand, von Kries and Nagel, and is further supplemented by new appendices and notes, some of which are by the German editors just named. It is perhaps regrettable that certain of Helmholtz's theoretical discussions, peculiar to the second edition, could not have been included. This is especially true of the second part or volume, dealing with visual sensation, to which Helmholtz made some very interesting additions. However, the subject-matter of these additions is treated in the appendices in a manner technically more adequate than that of Helmholtz, if lacking in the touch of his master mind.

The first of the three volumes of the English edition has already been reviewed in these pages. It deals

[1] Edition of 1853, Benjamin B. Muncy & Co., Boston, pages 180–.

[2] Italics mine.

with the anatomy and dioptrics of the eye, with appendices by Gullstrand. Its standpoint is primarily physical and physiological. The second and third volumes are concerned with problems which are essentially psychological in character.

Volume II treats of "The Sensations of Vision." The chapters by Helmholtz consider successively: "Stimulation of the Organ of Vision," "Stimulation by Light," "The Simple Colors," "The Compound Colors," "The Intensity of the Light Sensation," "The Duration of the Sensation of Light," "Variations of Sensitivity," "Contrast" and "Various Subjective Phenomena." There is an interpolated chapter by Nagel, dealing with "Changes in the Retina due to Light." A separate appendix by Nagel discusses "Adaptation, Twilight Vision, and the Duplicity Theory," and in about eighty pages brings this part of the subject quite well up to date. A second, somewhat shorter, appendix by von Kries is concerned with "Normal and Anomalous Color Systems" and "Theories of Vision." Under the first caption are treated "Laws of Mixture of Light" and "The Phenomena of Daylight Vision under Conditions that make it Difficult or Impossible to recognize Colors"; while under the second are considered "Modulations of the Organ of Vision" and "Temporal Effects of Stimulation," as well as the principal theories of color vision.

A new chapter on "The Nature of the Color Sensations," by Christine Ladd-Franklin, forms an important addition to the volume. After discussing the inadequacies of the Helmholtz theory of color vision, Mrs. Franklin stresses the importance of what she calls the Helmholtz-König *facts* of color vision. These are embodied in the curves of the three fundamental sensations, as computed to fit the view that the two species of dichromatic vision are "reduction systems" in which the green and red sensations, respectively, have dropped out. Here, Mrs. Franklin does the important service of presenting the exact graphs of the three sensations as found by König, compensating to some extent for the absence of certain significant portions of the second edition. Finally, she expounds anew her well-known developmental theory of color vision as a resolution of the combined difficulties of the Helmholtz and Hering views. The exposition is clear, concise and convincing. A chemical substance, a rosaniline carboxylate, has been noted which has decomposition reactions accurately paralleling those of the completely differentiated molecules postulated by the developmental theory.

The translator has added a valuable bibliography of papers which appeared between 1911 and 1924 treating topics allied to those of Volume II. There are also numerous new foot-notes, which distinctly modernize the discussion. One of the editors of the third German edition, von Kries, has contributed three long notes, bearing the date of 1924. The first (p. 300) deals with explanations of simultaneous contrast and favors the view that this phenomenon does not rest exclusively upon a physiological interaction of adjacent retinal areas, but has also a central or psychological basis, as advocated by Helmholtz. The second (pp. 411–413) discusses the recent papers of Hess directed against the classical view that normal, protanopic and deuteranopic color vision represent three distinct species without transition forms. Von Kries argues that Hess's observations are not adequate to refute the classical doctrine and that many of his facts are quite consistent with it. The third note (pp. 422–425) treats of recently proposed methods of heterochromatic photometry, including Pulfrich's stereophotometric scheme, which is discussed critically in some detail.

The third and final volume of the treatise bears the title: "The Theory of the Perceptions of Vision," and considers the processes—both physiological and psychological—by which visual sensory data are organized into a visual knowledge of the world about us. The translation presents in English the entire text of the third volume of the third German edition, with all the original notes and appendices by von Kries. There are also many new notes by the editor and his collaborators and two new contributions by von Kries. The volume comprises 734 pages, ending with a new bibliography of works on visual perception bearing dates between 1911 and 1925 and an index to the complete treatise.

The sections by Helmholtz have the following titles: "Concerning the Perceptions in General," "Movements of the Eyes," "The Monocular Field of Vision," "The Direction of Vision," "Perception of Depth," "Binocular Double Vision," "Rivalry between the Visual Globes" and "Review of the Theories." There are detailed notes to all these sections by von Kries, with the exception of the first section. The original appendices by von Kries concern "the spatial configuration in vision, with special reference to the questions of innate dispositions and experience," as well as "the theory of binocular instruments."

The two new notes by von Kries deal with illusory phenomena of binocularly perceived motion and binocular color mixture, respectively. In the first note (pp. 398–400), he discusses the experiments of von Szily, in which oscillating objects were observed with a reversing prism in front of one eye. In the second note (pp. 530–531), he reviews Trendelenburg's recent work, which indicates that binocular color-mixture is not only possible but yields the same results qualitatively as does monocular mixture.

The general make-up of the three volumes of the English translation is practically identical with that

of the third German edition. All the illustrations of the latter are reproduced. In fact, the identical cuts which were used for the German printing were employed in the American presses, thanks to the cooperation of the German editors and publishers.

Professor Southall and those who have assisted him in the translation of this stupendous work deserve the utmost praise. We must also laud the Optical Society of America and the generous benefactor who has insured the financing of a very expensive publication. Money could not and did not buy the affectionate effort which has produced this faithful interpretation of the original German; money will never repay those who have put this work into accessible form. But both the translator and the publishers receive their recompense in the knowledge that they have accomplished something tremendously worth while, which has been dreamed of for years by English-speaking scholars, but regarded by them as a practical impossibility.

LEONARD T. TROLAND
HARVARD UNIVERSITY

SCIENTIFIC APPARATUS AND LABORATORY METHODS

SURFACE TENSION MEASUREMENT BY THE RING METHOD

F. H. MACDOUGALL'S article on surface tension, published in SCIENCE[1] some months ago, makes an inference which if misunderstood will convey a wrong impression to the scientific worker whose investigations make necessary a measurement of surface tension. The article in question might be understood as meaning that the ring method because of supposed inherent inaccuracies is not a practicable tool in investigations that require reliable information about surface tension phenomena. Because of the fact that such an inference is far from fact, a brief discussion of MacDougall's criticism seems in order.

There will be no misunderstanding if the distinction between two kinds of accuracy is clearly made. Some investigators who are interested in the phenomenon of surface tension purely from its physical aspects will naturally think of accuracy as that attribute of the measurement by which the *n*th place in the surface tension constant becomes significant. On the other hand, to the investigator who is concerned not at all with the surface tension constant of pure liquids, but to whom surface tension values of a liquid medium tell a story of the changes that are taking place in the medium, the term accuracy as applied to his surface tension measurements will have an entirely different meaning. The former investigator will spare no pains nor time in eliminating and reducing to the utmost those factors which he recognizes as sources of error in his measurements. He may, for example, devote months to the selection of a capillary tube which is exactly right for his purpose. The latter is interested in obtaining data as rapidly as possible in terms of which he may interpret the phenomena in which he is primarily interested. Both are doing necessary and valuable work; but it is essential that their respective ideas of accuracy be not confused.

In his discussion MacDougall says, "I do not think that the simple theory of the experiment even with the procedure advocated by Klopsteg can lead to accurate values of the surface tension." The procedure to which he refers is that described in my communication to SCIENCE, XL, 319, 1924. His criticism indicates that he thinks of accuracy in terms of the *n*th significant figure in a surface tension constant. My suggestions were directed at obtaining accuracy sufficient for the purpose of the investigator who may find the ring method to be more time saving and easy to apply than any other.

Bearing in mind what has been said about the "practical" accuracy which is desired by the investigator who uses surface tension measurements as means to an end, I think it possible to show that the ring method with the procedure described in my earlier communication measures up to the requirements of such investigations. My demonstration is based on such an authority as Professor H. Freundlich, who in his "Kapillarchemie," published in 1923, gives the following table:

SURFACE TENSION OF WATER AT 18°

Method		Observer
Oscillating jets	73.0	Rayleigh
Oscillating jets	73.8	Pederson
Oscillating jets	72.4	Bohr
Oscillating jets	73.0	Lenard
Capillary waves	74.0	Rayleigh
Capillary waves	73.3	Dorsey
Capillary waves	73.8	Kalähne
Surface curvature	73.5	Lohnstein
Large air bubbles	73.0	Quincke (Reported by Worthington)
Capillary rise	73.0	Volkmann
Copper ring	76.8	Weinberg
Adhesion plate	73.1	Hall
Drop weight	73.8	Ollivier (Reported by Lohnstein)
Pressure in bubbles	75.2	Cantor
Pressure in bubbles	73.7	Magini
Pressure in bubbles	72.7	F. M. Jäger
Tensiometer, duNoüy	73.7	Klopsteg

[1] "Surface Tension determined by the Ring Method," SCIENCE, XLII, 290, 1925.

To these should be added several values which have not appeared in the tables of physical constants hitherto published.

Capillary rise	73.1	Harkins and Brown
Capillary rise	73.1	Richards and Carver

We may take for granted that the values mentioned in the table were obtained under carefully controlled conditions of observation and that the observers were competent to analyze their problems from the standpoint of eliminating gross errors. The unweighted average of their results should therefore give a value whose probable error may be assumed as not greater than a few tenths of a dyne. This average (omitting the values of Weinberg and of the writer, since theirs are results obtained by the method which is being compared with the others) is 73.4. The value of 73.7 obtained by the duNoüy tensiometer differs by only .3 dyne from this average, an agreement which is closer than that of most of the individual values given in the table. In the case of pure water, therefore, the ring method comes as near qualifying as an "accurate" method as most of the methods cited in Freundlich's table.

At another point in his discussion MacDougall states that my procedure "is undoubtedly correct," with the exception of the method for correcting for the droplets adhering to the ring. Speaking of the correction for the droplets, he states, "I hope to show that the magnitude of the pull on the ring is independent of whether the droplets are formed on the ring or not." So far as I can discover, there is no demonstration of this point, unless the statement, "if there is in fact a maximum pull, it is evident that its magnitude will be independent of such phenomena as the actual breaking of the film and the adherence of droplets to the ring," can be so considered.[2] Beyond stating that the conclusion is by no means obvious, I refrain from arguing this question, because, according to the standard of "practical" accuracy, the correction for the droplets may be ignored without affecting the value of the data.

The ring method of measuring surface tension has its practical limitations, of course; but this statement is generally valid for all methods of physical measurement. From the standpoint of greatest accuracy in determining the physical constant of surface tension for pure liquids it is probably not so well suited as some others because of the complicated mathematical relationships[3] between the pull on the ring and the actual surface tension value. The fact remains, however, that for practical purposes these complicated relationships are of small importance in most cases, since the correction involved is small from the standpoint of practical accuracy. The ease with which the ring method can be used, the speed of measurement attainable, and the agreement with values obtainable by methods that involve most exacting refinements render the ring method one of the best, if not the best, for the study of the phenomena which are associated with changes in surface tension. This has been amply demonstrated in the work of duNoüy as reported at the Third National Colloid Symposium.

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[2] The phenomenon of maximum pull, whether the ring or a straight edge is used, was observed by investigators thirty or more years ago. See, for example, Arthur L. Foley, *Physical Review*, III O. S., 381, 1896.

[3] "Zur Theorie der Abreissmethode," J. J. Tichanowsky, *Phys. Zschr.*, 26, 1925, 522. Tichanowsky in this article gives a mathematical analysis of the ring method employing rings having different kinds of cross sectional shapes. In this paper he investigates a "ring" having infinite radius but leaves the ring with finite radius for a future paper.

SPECIAL ARTICLES

THE EFFECT OF ADRENALIN ON THE LUMINESCENCE OF FIREFLIES

IN a recent paper by C. W. and H. H. Green[1] the effect of adrenalin on the luminous organs of *Porichthys notatus*, a California shore fish, was discussed. The authors found that an injection of adrenalin caused a brilliant glow of the luminous organs which persisted for several hours after the injection. From this and other experiments they came to the conclusion that the luminous organs of *Porichthys notatus* are hormone controlled rather than under nervous coordination.

It is interesting to note that an identical result is produced when adrenalin is injected into the body of a firefly (*Photuris pennsylvanica*). Although it is true that scattered masses of tissue of a similar staining reaction to that of the medulla of the suprarenal glands are known to occur in invertebrates, it is unlikely that the normal flashing of the firefly is controlled by hormones. The glow which is produced by the injection of adrenalin appears to be due to an abnormal condition resulting from the action of the drug on the myo-neural junction of the muscle

[1] "Phosphorescence of *Porichthys notatus*, the California Singing Fish," *Amer. Jour. of Phys.*, Vol. 70, 1924. Additional references given in these notes can be found, except when otherwise noted, in the bibliography of E. N. Harvey's monograph, "The Nature of Animal Light," or in that of his more recent paper, "Recent Advances in Bioluminescence," *Physiol. Rev.*, Vol. IV, No. 4, Oct., 1924.

fibers in the tracheal end-cells.[2] The normal flash of the insect is undoubtedly under nervous control. The innervation of the luminous organs has been described by a number of observers, notably Bongardt and Geipel, who found nerve fibers penetrating the tracheal end-cells. Within these cells are muscle fibers radially arranged around the tracheole in such a manner that their contraction increases the size of its lumen. The tracheole is surrounded by a small band which has been thought to be composed of circular muscle fibers.[3] Evidence from experiments with gases shows that the tracheoles are never completely closed in the normal insect. It seems more likely that the band is an elastic, chitinous ring which keeps the tracheoles partially contracted and serves as a point of attachment for the radial muscle fibers.

In general, adrenalin causes the contraction of smooth muscle, its point of action being the "receptive substance" in the myo-neural junction of non-medullated nerves. Very little is known in regard to its effect on invertebrates, but if we assume that adrenalin causes the contraction of the muscle fibers of the tracheal end-cells, and through this the enlargement of the lumen of the tracheole, the explanation for the prolonged glow is obvious, since an abnormally large amount of air is admitted to the luminous tissue as long as the tracheoles are dilated.

A 1:1000 solution of adrenalin chloride was injected into the insect just posterior to the last pair of legs. The movements of the legs and abdomen, at first violent, gradually cease and with their cessation appears the steady glow. That this is not due to mechanical stimulation through pressure of the injected fluid may be shown by injecting physiological salt solution. In this case no glow occurs. Injected insects recover and show a normal behavior after about six hours.

The extent to which the adrenalin affects muscles other than those of the tracheal end-cells has not yet been thoroughly studied. It is certain that some of the other muscles are not contracted by the injection. The muscles of the occluding apparatus, structures which surround the base of each tracheal trunk just inside the stigma, compress the trachea by their contraction, thus preventing the entry of air into the tracheal system. Conversely, their relaxation permits free ingress of air. That these muscles are not contracted is shown by the reaction of an injected insect to an alternating atmosphere of oxygen and nitrogen. Under such conditions the glow of the luminous organ follows the alternation of the gases with beautiful precision, becoming brilliant in oxygen and being extinguished in nitrogen. This could not occur if the muscles of the occluding apparatus were contracted by the adrenalin, but it may be questioned whether they are relaxed or whether normal breathing movements continue after injection.

In order to see, if possible, the actual effect of the adrenalin on the tracheoles of the luminous organ a histological investigation of the tissue was made. The abdomens were cut from injected insects and normal controls and fixed at once in hot Bouin's fluid. An injected and normal abdomen were together embedded in celloidon and paraffin, cut at six microns and stained with iron-haemotoxylin. In the normal tissue the tracheoles could, in a few cases, be followed a short distance into the surrounding tissue. For the most part they could not be seen at all. In the adrenalin injected tissue the tracheoles were very prominent and could readily be followed through the tissue from one cylinder to another.

The results of this initial study of the action of drugs upon the luminescence of the firefly point to the following interpretation of the process:

The normal flash of the insect is directly due to nervous control, but it is also indirectly dependent upon breathing processes. During the respiratory cycle of an insect there is a phase when air is forced into the finest tracheoles by the coordinated contraction of the abdominal muscles and those of the occluding apparatus. Except when the insect is flashing, the air permitted to enter the tracheoles of the luminous tissue is regulated by the size of the elastic ring to an amount just sufficient for the respiratory needs of the luminous cells. By the contraction of the muscle fibers of the tracheal end-cells and the consequent distention of the elastic ring at the instant when the air in the tracheal system is under pressure a much greater amount of air is admitted to the tracheoles of the luminous organ, thus causing luminescence.

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[2] For a general discussion of the gross structure and the histology of the luminous organs of fireflies see Dahlgren, "The Production of Light by Animals," *Jour. Franklin Ins.*, March and May, 1917.

[3] Dahlgren, *loc. cit.*

THE OHIO ACADEMY OF SCIENCE

THE thirty-sixth annual meeting of the Ohio Academy of Science was held at the Ohio State University, Columbus, Ohio, April 9 and 10, under the presidency of President Paul M. Rea, of the Cleveland Museum of Natural History, Cleveland, Ohio. The attendance was unusually large and enthusiastic, and the program was well received. Sixty-nine new members were elected and five members were elevated to the rank of fellows in the academy, namely, J. H.